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ABSTRACT

This paper attempts to connect theories of learning and theories of instruction, which often originate independently from each other, into a unified theory which gives a central place to students' self-regulation and which is based on recent research on student learning. The first of four parts analyzes the cognitive, affective, and metacognitive activities students use to learn and also discusses students' mental models of learning and their learning orientations. The second part examines the ways in which learning can be externally regulated by three basic instructional strategies: strong external control, loose external control, and shared control. The third part focuses on the interplay between self-regulation and external regulation and the congruences and frictions between these modes of control. From this interplay, the final chapter attempts to derive principles for the design of process-oriented instruction in different learning environments that would avoid destructive frictions and try to bridge the gap between learning and instructional design. Two tables give examples of instructional activities for various learning functions in strong external control and shared control environments. (74 references) (Author/NRP)

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THE INTERPLAY BETWEEN INTERNAL AND EXTERNAL REGULATION OF LEARNING, AND THE DESIGN OF PROCESS-ORIENTED INSTRUCTION.

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Contents **Page**

1. Selfregulation of learning 1
2. External regulation of learning 4
3. The interplay between external and internal regulation 9
4. The design of process-oriented instruction 12
5. Discussion 18
References 18

Abstract

Theories of learning and theories of instruction often originate independently from each other. Instructional design frequently takes place without using any theory of learning. In this paper an attempt will be made to connect the two types of theories into a unified theory of learning and instruction. The contours of the theory, which gives a central place to the learning and thinking activities of students and which is based on recent research on student learning, will be sketched. The paper consists of four main parts. In the first part the cognitive, affective and metacognitive activities students use to learn are analyzed, as well as their mental models of learning and their learning orientations. Next several ways in which instruction (teacher, book, computer, etc.) may regulate the learning and thinking activities of students will be discussed. Three basic instructional strategies that may be employed for this external regulation are examined here. The third part focuses on the different ways in which these instructional strategies and three degrees of selfregulation by the learner act upon each other. Congruences and frictions between these modes of control are discussed. Finally the principles of an alternative instructional style, derived from this interplay, are described. This process-oriented instruction promotes congruences, avoids destructive frictions, and tries to bridge the gap between learning and instructional design.

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1. Selfregulation of learning

Regulation of learning refers to exerting control over the content, course and outcomes of learning processes. This control is aimed at initiating and continuing the processing of learning contents, and uses knowledge about and views on learning processes. Regulation so performs an intermediate function between ideas about how learning processes may best be shaped and the actual realization of those ideas. This applies to designers of instruction as well as to students.

Instruction does not lead to learning automatically. The learning activities students employ determine to an important degree the quality of the learning outcomes they attain. To let learning take place, activities by the learner are necessary. Even when instruction is very well, eventually it are the students themselves who must acquire knowledge, insights and skills (Resnick, 1987; Brown, 1987; Shuell, 1988). Therefore this paper will start with an analysis of the way in which students learn, regulate their learning processes themselves and of the cognitive, affective and metacognitive activities they unfold in doing so. Next the external regulation of learning will be discussed. Examined will be with what instructional strategies learning may be regulated externally, and what the advantages and disadvantages are of these strategies. How the internal regulation by the learner and the external regulation by the instruction act upon each other is also discussed there. Finally an attempt will be made to derive from this interplay principles for the design of process-oriented instruction in different learning environments.

A first kind of learning activities are those thinking activities students use to process information and by doing so to attain their learning goals. Types of information that often appear in subject matter and at which these activities are directed are for example facts, concepts, formulas, reasonings, arguments, definitions, theories, views and conclusions. These *cognitive processing activities* lead directly to certain learning results at the mental level, such as knowledge, understanding, insight, and skill, or at the material level, for example notes, underlinings, a scheme, a paper and a summary. Research on the nature of these thinking activities identified the following eight categories as most important (Janssen & De Neve, 1988; Pask, 1988; Marton, 1988; Kolb, 1984; Schmeck, 1988; Svensson, 1984; Weinstein, 1988; Vermunt, 1987a).

Relating: looking for connections between different parts of the subject matter, between the parts and the whole, the broad outline of the learning content and between new information and the own prior knowledge or preconceptions.
Structuring: bringing together separate parts of information into an organized whole, trying to impose structure on the learning content and integrating newly acquired knowledge into the knowledge one already possesses.
Analyzing: breaking down a larger whole into the parts of which it is composed, sorting out step by step what different aspects may be discerned at a problem, line of thought or theory.
Concretizing: trying to form concrete images with abstract information, borrowed from phenomena one is familiar with.
Applying: exercising oneself in using knowledge and learning contents.
Memorizing: imprinting separate information by repeating it a number of times for oneself, and rehearsing subject matter.

Processing critically: thinking along with authors, teachers and fellow students, drawing own conclusions based on facts and arguments, and not accepting just anything that is said or written.
Selecting: distinguishing between main and minor points, reducing large amounts of information to the most important parts.

A second type of learning activities has to do with the role affective variables play in learning. These *affective processing activities* that students employ to process feelings that arise during learning, lead to a mood that may work out positively or negatively on the progress of the learning process. Based on research into the nature of these affective activities, they may be classified in a number of different kinds (Boekaerts, 1988; Corno, 1986; Kuhl, 1987; McCombs, 1988; Palmer & Goetz, 1988; Pekrun, 1988).

Attributing: ascibing the results that are reached in a learning process to causal factors: stable versus variable, controllable versus uncontrollable, global versus specific and internal versus external.
Motivating: building up and maintaining the will to learn, concerning general as well as taskspecific learning motivation.
Concentrating: directing attention to taskrelevant aspects and coping with action distracting, taskirrelevant thoughts and emotions.
Judging oneself: evaluating, deriving judgments about oneself as a learner, regarding one's general subjective competence or self-efficacy with respect to certain subjects.
Appraising: attaching subjective values to learning tasks resulting in the will or unwillingness to invest energy.
Exerting effort: performing thinking activities that require mental energy, constructive effort or mindfulness (Salomon & Globerson, 1987; Burtis, Chan, Bereiter & Scardamalia, 1989).
Generating emotions: generating, maintaining and restoring positive feelings of wellbeing, selfconfidence and commitment, and coping with negative emotions as anxiety, fear, anger, stress, uncertainty, doubt, frustration and helplessness.
Expecting: building up expectations about the course and outcomes of a learning process.

Research on affective aspects in learning is mostly aimed at controlling and regulating emotions in such a way that optimal cognitive progress can be made. Research on the role of emotions in gaining a better understanding of the subject matter is scarce to absent.

Metacognitive regulation of learning refers to exerting control over one's own cognitive and affective processing of learning contents. *Metacognitive regulation activities* are those thinking activities students use to decide on learning contents, to exert control over their processing activities and to steer the course and outcomes of their learning. This selfregulation may be performed more or less consciously. It concerns for example the flexible employment of different processing activities, depending on the circumstances and on interim results that are reached in the learning process. These metacognitive activities constitute a third type of learning activities and by several researchers the following categories are considered important (Brown, Armbruster & Baker, 1986; Friedrich & Mandl, 1986; Simons &

Vermunt, 1986; Schumacher, 1987; Wagner & Sternberg, 1987; De Jong & Simons, 1988).

Orienting: preparing a learning process by examining characteristics of the learning task, situation and assessment, thinking of possible and desirable learning goals, contents and activities.
Planning: designing a learning process and deciding on a plan of action based on the information the orientation provides.
Monitoring: actively observing during task performance whether the learning process proceeds according to plan, as one had imagined beforehand.
Testing: checking whether one understands, can remember, can apply the subject matter sufficiently, testing if the actually realized learning results are similar to those one had in mind.
Diagnosing: determining gaps in one's own knowledge, skills and mastery of the subject matter, examining possible causes of difficulties or successes that arise during learning.
Repairing: introducing changes in the original plan based on the results of monitoring, testing and diagnostic activities, deciding on alternative learning activities, goals and/or contents during learning.
Evaluating: judging the extent to which the ultimate learning results are in agreement with the planned final goals and to which the learning process has proceeded as one had imagined previously.
Reflecting: thinking over all things that happened during learning and thinking about learning, instruction, learning activities and learning experiences in general.

Instruction does not lead to learning activities automatically. The *mental models of learning* and instruction of students determine their interpretations of the regulation measures instruction takes. These interpretations and perceptions are then to an important degree responsible for the learning activities a student undertakes.

In educational psycholgy a shift in interest may be established from knowledge about the subject matter to conceptions of the phenomena the subject matter is about (Eylon & Linn, 1988; Perkins & Simmons, 1988). The whole of these conceptions and misconceptions is referred to as 'mental model' (Schnotz, 1987; White & Frederiksen, 1989). A mental learning model can be described as a coherent system of learning conceptions: conceptions and misconceptions of learning. Conceptions of learning and thinking activities for example are mental representations of learning activities that may be used to change certain prior knowledge or preconceptions in desired learning results (Kluwe, 1987). Students interpret an assignment as "make a summary", under influence of these conceptions, as for example "copy the most important facts and definitions", or as "express in your own words the argument of the author". To these mental models further belong conceptions of oneself as a learner, conceptions of learning objectives, of learning tasks, of learning and studying in general, and regulation conceptions. These last mentioned conceptions are views on the task division between oneself and others in learning processes, ideas about the division of responsibilities between oneself, instruction and fellow students (Simons & Vermunt, 1986).

These learning conceptions determine what students understand by 'learning' and in what way they interpret learning objectives, learning activities, and instructional

measures. They may be viewed as learning strategic prior knowledge or preconceptions. It are not the instructional measures that regulate students' learning behavior, but students' interpretations of these measures. If for example students have the opinion that activities like relating, structuring, motivating, testing and diagnosing are not their task, but should be performed by instruction, they are not inclined to employ these activities so readily when learning, even not when they are instructed to do so.

Not only mental learning models influence the learning activities students perform, via their interpretation of instructional measures, but also their personal goals and intentions with a course. These do not necessarily coincide with the learning objectives instruction finds most important. *Learning orientations* refer to the whole domain of personal goals, intentions, motives, expectations, attitudes, concerns and doubts of students in following an education or course (Entwistle, 1988; Gibbs, Morgan & Taylor, 1984). Often a distinction is made between intrinsic, extrinsic and achievement motivation. Research with adult students showed that in this population a large diversity of orientations exist. Some of these are vocational of nature, others more personal. Also more academic orientations can be found, as well as social orientations.

Learning orientations exert their influence on the learning activities students employ mainly via affective processes, especially the values students attach to a learning situation or episode. These appraisal processes determine in turn the mental effort students are willing to invest, for what cognitive, affective and metacognitive activities they are prepared to use this effort, and to what types of information in the learning content they pay most attention (Elshout-Mohr, Van Daalen-Kapteijns & Baltzer, 1989; Boekaerts, 1988).

A distinction may be made between spontaneous and induced learning activities. The first mentioned activities students use on their own accord, induced ones on the initiative of others like instruction. *Learning strategies* are combinations of learning activities students use on their own initiative (Shuell, 1988). Just as is the case with learning activities, also with learning strategies a distinction may be made between cognitive, affective and metacognitive strategies. It will be hard to find a student who employes all learning activities and who has all learning conceptions and orientations described above. In other words, students differ in their *learning styles* (Schmeck, 1988; Vermunt, 1987b). A learning style is conceptualized here as a coherent whole of learning strategies students usually employ, their learning orientation and their mental learning model, a whole that is characteristic for them in a certain period. So the term learning style is a superordinate concept in which connections among the cognitive and affective processing of learning contents, the metacognitive regulation of learning, mental learning models and learning orientations are united.

2. External regulation of learning

In traditional instructional design, instruction is mainly conceived of as the direct transmission of knowledge and skills to students. Central developmental tasks in this paradigm are, among other things, decomposing a complex learning task in atomic component tasks, formulating and sequencing the objectives and assessing the extent

to which these goals are met by the students. Instruction is here the regulating agency, that prescribes to a large extent how a learning process should proceed (Lowyck, 1988). However, rarely the mental activities are specified learners should undertake during learning and the way in which these should be initiated. Psychological research into learning nevertheless showed that knowledge and skills cannot be transmitted directly, but are the result of mental activity by the learner (Brown, 1987; Shuell, 1988). The quality of the learning outcomes students attain is largely dependent on the quality of the learning activities they employ. Therefore here will be attempted to sketch in outline an instructional theory that gives a central place to learners and their learning and thinking activities, and which is based on the analysis of learning described so far.

Learning is viewed here as developing a way of thinking and acting that characterizes the culture of a professional community. Such a way of thinking consists of two important elements: the mental models and conceptions that represent phenomena in the subject domain, and the thinking activities that construe, modify and use mental models to interpret situations in that professional domain and to act in them. This kind of learning is called *situated learning*. Central are the development of students' thinking skills situated in a particular domain, developing their mental models that determine how they interpret phenomena in that domain, and linking their mental models and thinking skills, in other words learning students to think in terms of conceptions and learning them to use these conceptions in the context for which they are prepared (Brown et al, 1989; Schoenfeld, 1989; Ennis, 1989; Perkins & Salomon, 1989). Accordingly instruction is viewed as making learners to employ the right thinking activities to construct, change and utilize their mental models. In this way thinking skills and conceptions are instructed in coherence and situated in a domain. This type of instruction is named *process-oriented instruction*. The most important tasks of instruction are in this view initiating, supporting and influencing the thinking processes students use to learn (Simons, 1989; Klauer, 1987; Palincsar, Stevens & Gavelek, 1989; Collins, Brown & Newman, 1989).

Regulation of learning can be performed by the activities described above. These may be employed by students as well as by instruction. Learning and instructional activities are each other's image and may be described in the same terms. Hence one can speak of *instructional learning functions*, that can be divided in processing, affective and regulation functions (Klauer, 1985; Rosenshine & Stevens, 1986; Simons, 1989; Shuell, 1988). The processing function of instruction concerns presenting and clarifying the learning content. The affective function refers to creating and maintaining a positive motivational and emotional climate in learners. The regulation function is aimed at steering the learning processes of students. From the viewpoint of influence on the thinking activities students use in learning, in essence three instructional strategies are possible to externally regulate learning processes. These vary in the way in which the tasks in learning are divided between instruction and student. They constitute three grades of external regulation and therefore also of the degree of control students are expected to exert over their learning.

In the first strategy the instructional learning functions are performed by the instruction and so there is a *strong external control* (Rasenberg et al, 1987; Korthagen, 1987; Rosenshine & Stevens, 1986; Simons & Vermunt, 1986). In table 1 examples of this are given. All these examples of instructional activities refer to one and the same

instructional strategy: taking over or substituting cognitive, affective and metacognitive activities from students. The strategy can be employed by instruction to clarify the subject matter and to facilitate, regulate and control the processing of this subject matter by students. In this way instruction takes learning activities out of the students' hands by performing these for them and, in doing so, minimalizes the need for students to utilize their thinking strategies. Their most important task is to remember what is presented.

Characteristic of the second strategy is that it are mainly the students who have the responsibility for performing the functions (Beukhof, 1987; Shuell, 1988; Vermunt & Van Rijswijk, 1988). Here instruction assumes that students will employ the right learning and thinking activities on their own initiative when learning. There is a *loose external control*. Examples are given in the first part of this paper. Instruction limits itself to presenting the learning content and testing the learning results. The call on the thinking activities of students is maximum. They are expected to be able to take care of the cognitive and affective processing of the presented learning content themselves and for the regulation of their learning. In doing so instruction capitalizes on the supposed skill in independent learning and thinking of students.

In the third instructional strategy the responsibility for performing the instructional learning functions is shared between instruction and students and so one may speak of a *shared control*. Students are continuously activated to carry out the various functions themselves when learning (Simons, 1989). Examples are presented in table 2. In all these examples instruction stimulates students to employ cognitive, affective and metacognitive activities themselves in learning. Implicitly this may be done by building up an argument in such a way that students are encouraged to think, explicitly by asking questions and giving assignments or tasks (Willems, 1989). When students have some responsibility for their learning processes and may make some decisions, they are stimulated to employ regulation strategies themselves and to develop their skill in using them. In this instructional strategy it is the task of students to carry out the functions and the task of instruction to activate students to do so.

From the perspective of influence on the learning activities students employ, every form of instruction may be characterized in terms of the matrix 24 instructional learning functions x 3 instructional strategies. In practice there is always a *task division* between instruction and students regarding who performs when which instructional learning functions. Instruction may for example capitalize on skills concerning the affective processes and the regulation of learning, but substitute cognitive processing activities. This kind of instruction is quite common in the first years of higher education. Here in lectures a lot of relations are explained, examples are given, etcetera, but the affective processing and the regulation of the independent preparation for an exam are viewed by lecturers as tasks of students.

The way in which designers and teachers usually make instruction also often has consistent, stylistic aspects that, just as is the case with the learning styles of students, are connected to their mental models of learning and instruction and to their instructional orientations. When an instructional strategy is employed with some consistency by teachers or designers under the influence of an instructional model or orientation, one may speak of an *instructional style*. If for example many thinking

Table 1. Examples of substituting instructional activities by instructional learning functions in a *strong external control*.

Function	Instructional activity
I. Presenting and clarifying the subject matter.	
Relating	Explaining relationships, giving analogies.
Structuring	Presenting overviews, summaries, schemes, graphics, tables.
Analyzing	Explicating in detail, explaining step by step.
Concretizing	Offering examples, applications, illustrations, films, indicating relations with practice.
Applying	Presenting interpretations of actual events in terms of the learning content, giving exercises.
Memorizing	Rehearsing the subject matter regularly, giving rehearsal units.
Processing critically	Presenting arguments in favor and against a point of view, pointing out different possible conclusions.
Selecting	Revealing the main and minor points, marking central concepts.
II. Creating a promoting affective climate.	
Attributing	Giving realistic attributions, ascribing failure mainly to internal, controllable, variable and specific factors.
Motivating	Presenting the learning content in a captivating way, generating interest.
Concentrating	Directing attention to taskrelevant aspects, building in variation and pauses.
Judging oneself	Giving positive and constructive judgments, showing confidence in the capabilities of students.
Appraising	Pointing out the relevance of a course or task.
Exerting effort	Giving tasks and assignments that require mental effort.
Generating emotions	Reassuring learners, inducing selfconfidence, removing fear and anxiety.
Expecting	Building up success expectations, making students believe in themselves.
III. Regulating learning processes	
Orienting	Giving introductions, ascertaining prior knowledge and preconceptions.
Planning	Informing learners of the learning objectives, contents, activities and pace, giving assignments, algorithms and heuristics.
Monitoring	Observing students' facial expressions, asking questions.
Testing	Administering tests, making students solve practical problems, having them paraphrase learning contents.
Diagnosing	Examining the kind and cause of problems with understanding, administering diagnostic tests.
Repairing	Giving additional explanations, providing directions for studying, problems, tasks, assignments and references.
Evaluating	Administering summative tests, supplying example exams.
Reflecting	Giving feedback on the course of a learning process and suggestions for improvement in the future.

Table 2. Examples of activating instructional activities by instructional learning functions in a *shared control*.

Function	Instructional activity
I. Presenting and clarifying the subject matter.	
Relating	Asking for similarities and differences, having theories compared, building up an argument that stimulates thinking.
Structuring	Instructing to make a summary, overview, scheme.
Analyzing	Giving a case with a study task, asking detailed questions.
Concretizing	Having students make connections with own experiences, making them think of examples.
Applying	Having students solve a problem, asking for the meaning for practice.
Memorizing	Administering exams that test factual knowledge.
Processing critically	Having students present arguments, presenting conflicting views, having a group discussion.
Selecting	Asking for main points, instructing students to mark central concepts.
II. Creating a promoting affective climate.	
Attributing	Stimulating students to make attributions based on a realistic diagnosis.
Motivating	Giving students personal responsibility for their learning processes.
Concentrating	Recommending not to study too long in succession, to study at a place without visual and auditive distractions.
Judging oneself	Stimulating to estimate the own competence and self-efficacy highly.
Appraising	Emphasizing the importance of a subject or task for realizing personal goals and intentions.
Exerting effort	Making students tell the results of their thinking process in a group.
Generating emotions	Having students experience successes, emphasizing their strong sides, praising them when their learning results improve.
Expecting	Giving tasks students can handle.
III. Regulating learning processes	
Orienting	Activating prior knowledge and preconceptions of students.
Planning	Giving students freedom of choice in determining the learning contents, objectives, activities and pace.
Monitoring	Having students ask questions, making them do an assignment in a small group with the task to monitor each others process.
Testing	Instructing to invent and answer test questions.
Diagnosing	Having students indicate what exactly they do not understand, making them formulate possible causes of incomprehension.
Repairing	Encouraging students to search for solutions on their own with difficulties, having them tackle problems together, giving hints.
Evaluating	Giving the task to compose an exam, to do each others exam and to consider it in retrospect.
Reflecting	Instructing to compare their own approach with that of others.

activities are consistently taken over from students, a substituting instructional style is in operation.

3. The interplay between external and internal regulation

Instructional and learning strategies are not always compatible. Between the selfregulation by students and the external regulation by instruction of a learning proccess complex interplays may take place. *Congruences* occur when the learning strategies of students and the instructional strategies are compatible, *frictions* when this is not the case. The outcomes of congruences are denoted with the term mathemagenic effects. Frictions result in interference phenomena, also named mathemathantic effects (Lohman, 1986; Clark, Aster & Hession, 1987). These are the case when the instructional strategy has negative effects on the learning process, learning results or the learning and thinking skills of students, or when instruction gives rise to misconceptions or lets them continue to exist. From the viewpoint of influence on the learning and thinking activities students employ, constructive and destructive frictions may be discerned. People often are very resistent to changes in their habits. Constructive frictions represent a challenge for students to increase their skill in a learning or thinking strategy. They may be necessary to make students willing to change and to stimulate them to improve their skill in the use of learning and thinking activities. Destructive frictions cause a decrease in learning or thinking skills. Here existing learning and thinking skills are not called on or potential skills are not developed.

As is the case with the external regulation of learning, three degrees of selfregulation by students may be distinguished. The first is that students master a learning activity well and use it skilled and on their own initiative. In the second case students master a learning activity only to a limited extent, or they master this activity well but do not use it spontaneously, in the right situations or sufficiently skilled in the subject domain. In the last case they do not master a learning activity and do not use it when learning.

With a *strong external control* in which instruction utilizes a substituting strategy, congruences occur when students do not master a learning or thinking strategy and when the distance between prior knowledge and the learning content is very large. This is for instance the case when students are not looking for relations within the subject matter and instruction explains these relations. Frictions between a strongly controlling instructional strategy and the learning strategies of students may be expected when students master and use a learning strategy well (Hamaker, 1986). In this case instruction is too obvious and with the students extinction of the concerning learning or thinking activity takes place caused by a lack of application (Entwistle, 1987; Clark et al, 1987). Frictions also occur with this instructional strategy when students master a learning activity only to a limited extent, or master it well but do not use it spontaneously, in the right situation or sufficiently skilled in the domain at hand. In this case students are impeded to develop potential skills. Both types of frictions are of a destructive nature.

With a *loose external control* in which instruction uses a capitalizing strategy, congruences occur when students master a learning activity well and use it on their own initiative and in the right situations. This is for example the case when instruction

does not undertake any activities to regulate the learning processes of students during their independent studying of texts, and students have the necessary regulatory skills at their disposal. Frictions may be expected when students donot or not sufficiently master the learning or thinking strategies that are called on, or when they do master these strategies but donot use them on their own initiative in the right learning situations. When the degree of selfregulation by students is not adequate and also the external regulation is deficient, the danger of a lack of regulation is present. This is for example the case when instruction capitalizes on selfregulated strategies but a student is uncapable to perform these, wants to use an externally regulated strategy but does not get enough directions for it (see Rasenberg et al, 1987; Korthagen, 1987). Both these frictions may work out constructively as well as destructively, depending on the distance between the learning style of a student and the learning and thinking activities instruction calls on (Willems, 1987).

In a *shared control* in which instruction uses a lot of activating strategies, congruences occur when students master a learning activity only to a limited degree, or master it well but do not use it spontaneously, in the right situation or sufficiently skilled in the subject domain. An example is that students do not process a learning content critically on their own initiative, but are nevertheless stimulated by a group discussion to draw their own conclusions and to form personal judgments. In this shared control constructive frictions will take place when students do not master a learning or thinking activity in the subject domain at hand. Destructive frictions may be expected when students master a learning or thinking activity well and use it spontaneously and in the right situations. One can imagine that students who are able to regulate their learning and thinking processes on their own, get irritated and out of balance when instruction tells them continuously what and when to do (Lohman, 1986).

Students do not always behave in the way teachers or designers of instruction imagine them to do. There may be several reasons why students do not utilize a thinking strategy, in spite of the fact that instruction activates to or capitalizes on the use of it. A first category of reasons consists of it that students do not, or only to a limited degree, master the concerning strategy. The distance between the learning style of students and the desired strategy is then too large. This has already been discussed in the previous sections.

A second category has to do with the distance between the domain knowledge or preconceptions of students and the learning content. A thinking skill may be mastered at a certain level of complexity and abstractness in a domain, but that does not mean that this strategy can also be used in a skilled way with more complex, abstract, divers and voluminous learning contents within the same domain, or at the same level of these but then of other domains. Learning to learn and learning to think not only means learning new thinking skills, but more often learning to use existing thinking skills to process learning contents that get increasingly complex, voluminous and abstract, and to regulate this processing. When for example the distance between domain knowledge of students and the learning content is very large, looking for relations, examples and structures does not result in finding these relations, examples and structures. The consequence may be that students do not use the particular, successless thinking activities any more. When on the contrary the distance between the domain knowledge of students and the learning content is very

small, they understand immediately what is meant, learn little new things and there is little need for using whatever thinking strategy. In both cases capitalizing or activating by instruction does not have the intended effect on the learning activities of students.

A third category of reasons has to do with the mental learning models of students (Peterson, 1988). Instructional measures never directly influence the learning and thinking activities students employ, but always via their interpretations of the taken measures. These interpretations determine how instructional measures are used by students. They are made in terms of the mental models of students, consisting of conceptions of learning and thinking activities, learning goals, learning tasks, oneself as learner, learning in general and the regulation of learning. It is for example possible that students and teachers or designers do not have the same regulation conception and different views on the task division between students and instruction. When students think it is not their task to motivate themselves or to exert mental effort, the results of activating or capitalizing instructional strategies are more likely to be negative opinions about the offered instruction than an increase in the use of these learning activities. Students may also understand something different by a learning activity as making a summary, than teachers or designers have in mind when they activate students to do so.

A fourth category of reasons why students do not always behave as intended by teachers or designers of instruction is located in their learning orientations. These determine how instructional measures are appraised by students and by that also how they are used. Students may not find it worth the trouble, time and effort to perform the learning activities to which they are activated. Questions added to a text with an activating intention may for example be skipped on the grounds of such an appraisal. The personal goals and intentions of students may to a more or lesser extent agree with the learning objectives instruction formulates. Students who study mainly out of personal interest perhaps have the tendency to carry out study tasks they find captivating with more mental effort than tasks that contribute less to the realization of their personal intentions.

People have the tendency to avoid frictions and to seek congruences. The *origin of learning styles* may be explained in a long-term adaptational perspective. Learning strategies and learning styles are also outcomes of instruction, intended or not (Schmeck & Geisler-Brenstein, 1989). With *congruences* the present learning style of a student will be strengthened. When for example students unfold too little learning activities spontaneously, and instruction stays using substituting strategies, students stay dependent on the instructional means (Laurillard, 1987).

With frictions students have at first the tendency to adapt to the present learning environment (Morgan, 1988). When this succeeds there is a *short-term friction*. When students for example stay in a learning environment in which in every possible way a picture of learning is communicated as in essence the intake of externally provided knowledge, they are likely to develop mental learning models in which this view is reflected. These models determine to a great extent how students interpret concrete learning tasks, which learning strategies they hold for possible and which from those they choose to use. Because people are resistent to change in their learning habits, short-term frictions may be necessary. The adaptational capability of students may

be expressed in the maximum distance between their present learning style and the desired style they can bridge when frictions occur.

When short-term adaptational processes lead to unsatisfactory results, other mechanisms come into play. *Long-term frictions* between learner and learning environment may result in an out-of-regulation learning style. Frustration may arise when an employed learning strategy repeatedly does not lead to the intended learning outcomes. In such a case these learning goals will be marked as unrealistic or the employed strategy as unusable in the mental learning model of students. Helplessness may arise when students cannot think of a suitable strategy to approach study tasks again and again. They miss the mental representation, conception of adequate strategies. In these cases such study tasks will be marked as impossible in their mental learning model. Anxiety and uncertainty may arise when students cannot reach satisfying interpretations of what is expected from them, of their progress in a learning process, and the like. In these cases such learning situations will be marked as threatening in the mental learning model of students, resulting in avoidance reactions regarding these situations. On repeated occurrence of these emotions an out-of-regulation learning style is the long-term outcome in all three cases.

4. The design of process-oriented instruction

Destructive frictions often occur. Designers of instruction for instance frequently have the tendency to take over as many learning and thinking activities from students as possible (Brown et al, 1989). Developing, *process-oriented instruction* tries to promote congruencies and to avoid destructive frictions. The aim is seeing to it that learners employ the right learning and thinking activities to construct, change and utilize their mental models of the learning content. This instructional style emphasizes a gradual *transfer of control* over the instructional learning process from the instruction to the students. The regulation conception that underlies it assumes that it is impossible and undesirable to carry out the learning processes for students and to exert maximum control over them. The tasks of instruction are in this conception mainly located in composing the learning materials and in initiating, supporting and influencing the thinking activities students use to learn (Simons, 1989). In process-oriented instruction situated learning is promoted: domain knowledge and conceptions of subject contents as well as learning and thinking activities, strategies and skills constitute the learning content. Process-oriented instruction may be applied within a variety of instructional orientations. Here its characteristics will be described.

Situated teaching of thinking skills. This principle implies that cognitive, metacognitive and affective activities should be taught in the context in which they are to be used. In a previous section learning was viewed as developing a way of thinking and acting that typifies the culture of a professional community. Mental models representing phenomena in a subject domain, are in this type of learning continuously connected to the thinking activities that construe and modify such mental models and use them to interpret situations in that subject area and to act in them (Brown et al, 1989; Schoenfeld, 1989; Collins et al, 1989; Ennis, 1989). In this way training in thinking skills takes place integrated and intertwined with instruction of the subject content, by which domain knowledge and strategic knowledge are taught in continuous coherence (Palincsar et al, 1989; Schoenfeld, 1988; Bereiter & Scardamalia, 1987).

The role of instruction is one of model, activator, monitor and evaluator of thinking strategies by students.

Cognitive apprenticeship and scaffolding. Process-oriented instruction is characterized by a gradual shift in the task division in the instructional learning process from instruction to students. First a strong, explicit external control structure is provided to students and subsequently the offered support is gradually withdrawn, with a simultaneous stimulation to have students internalize this external control over their learning processes and to perform it themselves (Reeve, Palincsar & Brown, 1987; Schoenfeld, 1989). Learning to learn and learning to think then mean a gradual transfer of control over learning processes from instruction to students, a gradual transition from external to internal regulation.

Diagnosing thinking strategies and domainspecific conceptions. This principle has to do with learning to know the students that participate in the instruction with the purpose of avoiding interference, destructive frictions and mathemathantic effects (Lohman, 1986; Clark et al, 1987). Because the occurrence of frictions originates from a certain combination of instructional strategies with the prior knowledge and learning style of students, adequate diagnoses of domain specific preconceptions as well as the thinking strategies and learning styles of students form a necessary condition to avoid these frictions (Weinstein, 1988). These diagnoses show what learning and thinking activities students master, how they think about learning and instruction, what their learning orientations and personal goals look like and what their domainspecific pre- and misconceptions are. In this way instruction can be tailored efficiently to developing those learning and thinking strategies students donot master or master insufficiently, and to those ideas about the content domain that prevent the development of usable, right and complete conceptions.

Adapting to learning styles and preconceptions. Students differ in the learning and thinking activities they employ of their own accord (Schmeck & Geisler-Brenstein, 1989). To avoid destructive frictions process-oriented instruction is tailored to the learning and thinking activities students master and use, their learning styles and their prior knowledge. This may be done on student as well as course level, with regard to the learning content, learning goals, learning activities and learning pace (Corno & Snow, 1986). Based on diagnoses of their learning style and prior knowledge different students get for example different assignments, tasks and questions. In some learning environments this individual differentiation is however better feasible than in others. Computer-based instruction lends itself well to it, a lecture in front of a hall with 500 students less well. In cases like these process-oriented instruction differentiates on group level. It is tried to tailor instruction to the mean prior knowledge and learning style of a group of students. A group of adult students is for example approached differently from a group of adolescent students. Differentiation changes via this groupwise form into adapting to the mean learning styles and preconceptions of the entire group of course participants (Weinstein, 1988).

Creating constructive frictions. Sometimes constructive frictions may be necessary to make students willing to change (see also Elshout-Mohr, Van Daalen-Kapteijns & Baltzer, 1989). Especially learning and study habits that already exist for a long time are not always easy to alter. In such a case constructive frictions may be helpful to make students realize that their present ways of learning and thinking no longer

suffice. This may for example be done by capitalizing on skills they do not master or by activating such skills. Students then enter a phase of reflection on their current approach and of exploration of alternative learning and thinking strategies, in which they are most open for new possiblities. Correct diagnoses of their learning styles and prior knowledge may prevent these frictions to work out destructively, because instruction then has the opportunity to stay within students' zone of proximal development. Frictions often occur when students enter a new type of education, for instance after the transition from secondary to higher education.

Teaching cognitive, affective and metacognitive activities in coherence. The three types of learning activities show a mutual cohesion. Affective activities may hinder or promote an effective use of cognitive activities. Regulation activities do not take place in a vacuum, but are directed at the cognitive and affective processing of learning contents. Training in isolated cognitive activities, without paying attention to their regulation, has proved little successful (Brown, Armbruster & Baker, 1986). On the other hand there is little sense in learning students how to regulate cognitive activities they do not master. Process-oriented instruction is aimed at promoting a flexible, versatile, selfregulated way of thinking and learning. In view of the mutual relations among types of learning activities in this form of instruction, cognitive, affective and metacognitive activities are taught in cohesion. This integrated instruction has proved to be most successful, in terms of improvement of the learning results, durability in the spontaneous utilization of the newly acquired cognitive, affective and metacognitive skills, as well as transfer to other and deviating tasks (Derry & Murphy, 1986; Weinstein & Mayer, 1986; Scardamalia et al, 1989; McCombs, 1988).

Demonstrating usually covert learning and thinking activities overtly and explicitly. Substituting thinking activities does not contribute anything to the development of skill in using them, and may cause frictions when this instructional strategy is employed in isolation. However, by carrying out this taking over of strategies as explicitly and overtly as possible, it may well perform a modelling function. By demonstrating the different activities by which learning contents may be processed and this processing may be regulated, instruction makes knowledge construction activities that usually stay covert and implicit, overt and explicit (Scardamalia et al, 1989; Simons, 1987). By temporarily taking over learning activities from students instruction functions as model learner and thinker, who demonstrates learning and thinking activities important for the subject domain. Instruction shows students for example how they may structure the central concepts of a domain into a scheme, how they can motivate and concentrate themselves, and how they may test their understanding of the learning content.

Activating students to use learning and thinking activities. After demonstrating learning and thinking activities, instruction should activate their use by students. By means of questions, assignments, study tasks, the way of presenting an argument and the like, students are stimulated to use thinking activities when learning they usually do not employ, not well or not enough on their own initiative (see table 2). Students are for example instructed to make a scheme, think of examples, plan learning goals or invent test questions. In this way students get the opportunity to increase their skill in using learning and thinking activities by exercising them. Instruction has the role of coach here. It acts as external monitor and provides students with feedback on the

quality of their performance of the thinking activities, so they may adapt the execution if necessary (Simons, 1989; Fischer & Mandl, 1988).

Capitalizing on learning and thinking skills. If skills cannot be used they decrease. When students develop learning and thinking skills, they also should get the opportunity to employ them. After a phase of activating thinking activities by instruction also this form of external regulation is gradually withdrawn. The call on a selfregulated use of these thinking activities increases proportionally. Instruction is now shaped in such a way that the newly acquired thinking skills are continually addressed and students also need them. This means that the degree of control students may exert over their learning also increases and choices regarding learning and thinking activities, learning contents, goals and the learning pace come more in the hands of students (Laurillard, 1987; Janssen & De Neve, 1988). This opportunity for selfregulation given to learners may promote their intrinsic motivation, have a beneficial effect on their selfconfidence and stimulate the use of deeper processing strategies (Morgan, 1988; McCombs, 1988; Ramsden, 1988).

Developing the mental learning model. The way in which learners interpret a learning situation and the instructional measures that form a part of it, determines to an important degree the learning and thinking activities they perform. Because these interpretations are governed by the mental learning model learners have, in process-oriented instruction attention is paid to developing correct, usable and complete mental learning models. Articulation of and reflection on learning and thinking strategies are important mechanisms to achieve this (Collins et al, 1989; Schoenfeld, 1989). Students are activated to reflect on the thinking strategies they use, on their own learning style and those of others. By dwelling on learning and thinking activities which existence or usefulness for a domain they had not suspected, by comparing their own task approach, learning orientation, learning conceptions, and relations among them with those of others, students gradually get more aware of their own and other possible learning and thinking activities (Vermunt & Van Rijswijk, 1988). This is especially important to ensure durability and generalization of learning and thinking strategies that are taught. By many authors the importance of this development is stressed. Marton (1988) for example sees this as an important means to improve student learning. Entwistle, Odor & Anderson (1987) use computer simulation to make prospective students realize the requirements of higher education.

Taking the learning orientation into account. The way in which learners appraise a learning situation and the instructional measures that form a part of it, also determines to an important extent the learning and thinking activities they are willing to employ. Because these appraisal processes are mainly governed by the learning orientations of students, in process-oriented instruction the personal goals and intentions of students are taken into account. The promotion of intrinsic orientations is the main aim here, taking into account that these may for example have a vocational, academic or personal nature. In the way mental learning models of students may be developed by activation of reflective activities, the development of intrinsic orientations may be promoted by activation of primarily affective activities. Appraisal processes can for instance be influenced by giving students freedom of choice in determining their learning contents, activities, goals and pace (Morgan, 1988). They may be given tasks in which they can realize their personal goals, for example by

having them write an essay on a subject they can choose themselves. Intrinsic motivation may also be strenghtened by stressing students' personal responsibility (McCombs, 1988).

Promoting transfer. Transfer of strategies seldom occurs spontaneously (Gray & Orasanu, 1987; Brooks & Dansereau, 1987). In process-oriented instruction high as well as low road transfer of learning and thinking strategies is encouraged (Perkins & Salomon, 1989). Low road transfer takes place through frequent, more or less mindless exercising of strategies in a large variety of situations and results in automatism. High road transfer occurs by mindful abstraction and decontextualization of strategies and principles and results in development of the mental learning model. Since different kinds of learning tasks call on different learning and thinking activities, offering students a variety of tasks is a means to increase their skills in the use of a varied array of thinking activities. The high road transfer is promoted by stimulating metacognitive activities like reflection. So in process-oriented instruction no middle road is chosen between situated learning and transfer, but both are stressed actively and alternately.

Presenting the learning content. The instructional strategies and principles described so far may take a concrete form in the way the learning content is presented (Schnotz, 1987; Glynn, Andre & Britton, 1986). This can be in written form, as in a study text, or in oral form, as in a lecture. By describing not only the central concepts but also explaining extensively the relations among them, instruction takes over relating activities from students. An activating effect may be reached by weaving questions into a text or oral presentation, making conflicting statements, etcetera. A capitalizing instructional strategy limits the giving of examples, the explaining of relations, and the like so students have to do that more by themselves. In a process-oriented presentation of the learning content as many of the above described principles as possible are applied. For example, no learning and thinking activities that students master are taken over from them, because then their level of mental effort decreases too much. The presentation is adapted to their prior knowledge and preconceptions, and to their learning and thinking skills. Learning contents increase in complexity and diversity and a progression takes place from activities embedded in a learning task to their generalization (Brown et al, 1989; Schoenfeld, 1989).

Constructing adjunct instructional means. Instructional strategies and principles may also be concretized in means that are added to the actual learning content (Hamaker, 1986; Andre & Thiemann, 1988; Willems, 1989). This too can be done in written, oral, or electronic form. By supplying introductions, learning objectives, selftests and the like instruction may take over regulation activities from students. By giving study tasks and assignments and by asking questions instruction may use an activating strategy. In a capitalizing strategy the use of these adjunct aids is largely kept back. Just as is the case with the presentation of the learning content, in process-oriented instruction as many of the above described principles as possible are applied in the construction of the adjunct instructional means. Based on selftests of a diagnostic kind students are for example refered to certain adjunct aids, that are tailored to the learning and thinking activities they employed and to their domain-specific misconceptions. The way in which these instructional means are used by students largely depends on their prior knowledge and preconceptions, their mastery of the learning and thinking skills called upon, their mental learning model and

their learning orientation. When this is not taken into account, adjunct aids often donot have the effects intended by the designer (Marton, 1988).

Composing the test. Students' learning behavior is strongly regulated by expectations regarding the test or exam. For process-oriented instruction this means that the employment of the thinking activities at which instruction is directed, should be awarded with a good test result. In concrete terms this means that tests are composed based on the eight processing functions described earlier. To stimulate the employment of other processing activities than memorizing, conceptions and mental models of phenomena dealt with in the learning content are tested instead of just knowledge of this learning content (Marton, 1988; Schoenfeld, 1988). To strenghten the employment of thinking activities by learners it is furthermore important that the test is in agreement with the other instructional means. It is for example quite common that the learning objectives presented at the beginning of a course, deviate from the objectives as operationalized in a exam. In process-oriented instruction transparancy of exam requirements is an important design principle (see also Janssen & De Neve, 1988).

Sequencing the instructional principles. A gradual transfer of control over learning processes from the instruction to the students implies a certain sequence in which the different principles should be applied. The 15 principles of process-oriented instruction discussed so far, can be divided into 4 more general and 11 more specific principles. General principles are always in operation. To these belong the situated teaching of thinking skills, cognitive apprenticeship and scaffolding, presenting the learning content and constructing the adjunct instructional means. Specific principles are employed in a certain sequence during a limited period of time. In the first phase of process-oriented instruction the thinking strategies and preconceptions of learners are diagnosed, instruction is adapted to their learning styles and prior knowledge assessed just before and, if necessary, constructive frictions are created. In the second phase the cognitive, affective and metacognitive activities are taught students donot master, donot master sufficiently, or do master but donot employ them spontaneously, in the right situations or sufficiently skilled in the domain. First a learning or thinking strategy is demonstrated overtly and explicitly, the student being observer. Gradually this demonstrating decreases and students are activated more to the use of the strategy in the subject domain, receiving process-oriented feedback. Later on also this activating support is gradually withdrawn and, by creating a challenging environment, instruction capitalizes on the spontaneous and right employment of the strategy by students. In a third phase durability and generalization are central. In this phase principles like developing the mental learning model, taking the learning orientations of students into account and promoting transfer are called into operation. The fourth phase consists of the test. A process-oriented test is in essence identical to the diagnoses of thinking strategies and domainspecific conceptions that took place at the beginning of instruction. The difference between these two diagnostic moments is the learning effect. This shows to what extent thinking skills have been improved and mental models of the learning content have been developed.

5. Discussion

With regard to the selfregulation of learning by students it turns out that some areas are not yet sufficiently studied. For example, little is known about the relations among learning activities within the cognitive, affective and metacognitive domains, as well as about relations among these domains. Also relations between the learning strategies students employ and their mental learning models and learning orientations are yet insufficiently researched. The extent to which and the way in which subject domains and thinking strategies are connected is also an area that still needs a lot of research. What differences and similarities do for example exist in the way students of different subject areas unfold learning and thinking strategies? What does the connection between domain knowledge and strategic knowledge mean for the extent to which transfer is possible to other domains? Also the role of affective processes, such as exerting effort, in bringing about learning results is a research area still hardly exploited.

Process-oriented instruction is a relative new form of instruction, so it is not surprising that many aspects of it are not yet well researched. For example, it is still unclear what exactly the mechanisms are that determine how students interpret, appraise and use the instructional measures. How the different degrees of external and internal regulation operate upon each other, and whether this happens differently in different kinds of instruction, such as distance education and regular contact education, is also a point for further study. How do the learning objectives, tasks and assignments, questions, tests and feedback instruction provides, interact with the learning objectives etcetera learners put and give to themselves? The influence of the degree of agreement between the mental models of learning and instruction and between the orientations of students on the one side, and those of teachers and designers of instruction on the other side, on the learning processes and results of students is hardly studied. Also little is known about the question when exactly frictions work out destructively and constructively.

Forthcoming research should also be directed at the way the transfer of external to internal regulation of learning and thinking processes can be realized concretely in different learning environments. The force of the different instructional principles should be established in research too, as well as the most optimum coherence among them. Maybe some learning environments are better suited to implement certain instructional principles than others. Furthermore an important task for research is to examine with what instructional measures the mental learning models and learning orientations of students can be influenced. Research we are currently doing addresses some of the questions raised here.

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